ART. XIX. –*On the Origin and Relationship of some Victorian Igneous Rocks.*

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Contents.

I. Introduction.

During the past several years I have been engaged in conjunction with Professor Skeats in making a careful study of the igneous rocks of the Macedon District. An account of our work in this area has recently been published as a Bulletin of the Geological Survey of Victoria (19), but since that paper went to the press I have continued to work on the question of relationship and differentiation of the two igneous series which are so well developed in the neighbourhood of Macedon and Woodend. This has led on to the study of the relationship of the Macedon dacites and granodiorites to rocks of other areas in Victoria, and the evidence that has been collected seems to have considerable bearing on certain aspects of modern petrology.

The most important point to be raised is the relationship of the so-called alkaline and sub-alkaline or calcic groups of rocks to one another. Harker (4) believes that these two branches of igneous rocks are quite distinct from one another, and that the former

branch is fundamentally associated with tectonic movements characteristic of the Atlantic coast type, and the latter is associated with the Pacific coast type of earth movements. Evidence will be advanced in opposition to this belief, and to show that in Victoria the non-calcic granites are genetically related to the calcic dacites and granodiorites.

Professor Skeats and the author have already expressed the belief that the alkaline rocks of the Macedon District represent a fractional differentiation product from the calcic basalt magma.

If these two contentions be upheld, then it follows that the correlation of alkaline rocks with subsidence due to faulting and the correlation of calcic rocks with folding, due to lateral compression, is open to grave objection.

The differentiation of rock magmas will be discussed at some length, but more with the view of determining the relationships of the end products to one another than to attempt any explanation of the means whereby these end products are derived from the parent magma.

II. Victorian Igneous Rocks.

(a) *The Macedon Granodiorite-dacite Series.*

In the Macedon District there are extensive developments of rocks belonging to two very distinct cycles of igneous activity. The older of these series has been shown (19) to consist of dacites, granodiorites and granodiorite porphyries. The dacites were in part extrusive and in part intrusive, and were closely followed by the intrusion of the granodiorites and granodiorite porphyries. It is quite impossible to definitely fix the age of these rocks, as they were intruded through and into rocks of Ordovician age, and are overlain in part by sands and lavas of Kainozoic age. However, for reason given elsewhere it is highly probable that these rocks are of Devonian age.

(b) *Victorian Upper Palaeozoic Series.*

Dacites similar in every respect to those of the Macedon District occur in the Dandenong Ranges and in the neighbourhood of Healesville. Mineralogically and texturally these dacites are entirely comparable with those of Macedon. Phenocrysts of plagioclase, hypersthene, biotite, and occasionally quartz, are set in a granulitic groundmass consisting mainly of quartz and felspar, with some biotite, ilmenite and minor accessories. Naturally there are textural variations, but the above brief description can be applied to the majority of sections examined from Macedon, Dandenong Ranges and Healesville.

Northward from Healesville in the Cerberean Range, and in the northern portion of the Strathbogie Range, a rather coarser rock is the prevailing type. Taking the occurrence at the road-metal quarry at Violet Town as a type of the Strathbogie rocks, the following brief description may be given here.

This rock consists of phenocrysts of plagioclase (acid labradorite), abundant biotite, sparing hypersthene with a moderable amount of quartz in a granulitic groundmass similar in every respect to that described above as occurring in the dacite, except that it is somewhat coarser in grain. The phenocrysts are distinctly larger than those found in the dacite, and there is a larger amount of free quartz present. Garnets are not uncommon throughout this area. An analysis of the material from the Violet Town quarry was made a few years ago for me by Mr. G. Ampt, but has so far not been published. This analysis, which is given later, compares fairly closely with those of the dacites, but as was expected from the microscopical examination, it shows a decidedly higher percentage of silica.

The chemical and mineralogical characters of this rock are sufficiently closely allied to those of the Macedon dacites to cause us to regard them as genetically related to one another.

The southern portion of the Strathbogie Ranges consists of a granitic rock which provisionally may be referred to as adamellite. Frequently there is no hard and fast line of demarkation between the quartz-porphyrite of the northern portion and the adamellite of the southern. To the southward the quartz porphyrite becomes much coarser in grain, and might well be described as adamellite porphyry, and in places passes imperceptibly into adamellite. Near Euroa the junction is more marked, as a fairly broad area of even-grained aplite is found separating the adamellite porphyry from the adamellite. An examination of the junction of this aplitic rock with the porphyry shows that the aplite is intrusive into the latter, as veins from the former can easily be traced running out from the main mass into the adjoining porphyry. The relations of the aplite to the adamellite are not so clear, but apparently the aplite is also intrusive into the adamellite. The inference I make from a study of this field is that the quartz porphyrite and adamellite porphyry are the older rocks, and that as in the case of the Macedon and other dacite areas, the granitic rock was subsequently intruded. The difference noted between the contact in the dacite areas and in this area may be due to the fact that the dacite was largely effusive, whereas the field evidence and microscopical

character of the northern Strathbogie rocks tends to show that they were entirely intrusive in character. One might picture first an intrusion of the porphyry, followed at a short interval by a more deep-seated intrusion of adamellite. Subsequent cooling and contraction left an opening at the junction for the intrusion of the still molten, somewhat more acid residuum. Except for a slight schistocity there is very little evidence of contact metamorphism in the porphyry, such as has been noted at Macedon, Belgrave and elsewhere in the dacite. This might be explained by the fact that the temperature of the aplite at its intrusion would be relatively low, and the resultant metamorphism would be almost negligible.

The adamellite of the Strathbogies can be traced continuously from the neighbourhood of Seymour to the Broken River, near Nillahcootie. I have shown (22) that during the ascent of Mount Samaria, in this neighbourhood, granite, granite porphyry and quartz porphyry are successively met with, and there is little doubt that the three types belong to the one intrusion, the structural variation being due to the different pressures under which the rocks crystallised. The above rocks would be better described as adamellite, adamellite porphyry and quartz porphyrite. Eastward from Mount Samaria the prevailing type is a quartz porphyrite similar to that found at the summit of the mount.

The granular groundmass so typical in the dacites and the Strathbogie quartz porphyrite is generally absent in the Mount Samaria and Tolmie porphyrites, its place being taken by a fine-grained cryptocrystalline aggregate.

Hypersthene is absent in most sections examined, but several sections of the rock from Burn's Track, near Tatong, showed this mineral, and in these sections the granulitic groundmass was present. The field evidence shows that the quartz porphyrites of the Tolmie Highlands and of the Strathbogies belong to the one great period of intrusion, and this is supported by the general similarity of the micro-structure of the rocks in the two areas. This relationship has been given in some detail because the age of the dacites and allied rocks largely hinges on the evidence obtainable in this area.

The field evidence in the Macedon District shows that the dacites are post Upper Ordovician, and are younger than the Kainozoic igneous rocks of the area. The dacites of the Dandenong Ranges and Healesville are post-Silurian. The Strathbogie and Tolmie adamellites and quartz porphyrites are intruded into the Silurian, and these rocks in the southern portion of the Tolmie area are

overlain by the Mansfield sandstones. There is some little doubt as
to the age of these sandstones, as McCoy (11) described them as
equivalent to the Old Red sandstone, but later Woodward (24) has
placed them in the Lower Carboniferous. In any case, however, the
age of these rocks in the north-east of Victoria is confined to fairly
narrow limits. They are post-Silurian and pre-Lower Carbon-
iferous, i.e., they are almost certainly Devonian. Enormous earth
movements marked the opening of the Devonian in Victoria, and
there is no evidence of intense earth movement in Middle and Upper
Devonian, so that the inference is that the intrusion of these igneous
rocks accompanied these Lower Devonian earth movements, and
consequently are of Lower Devonian age.

The closely-marked similarity between the mineralogical and
micro-structural features of the dacites and the quartz porphyrites
lead one to the conclusion that they belong to the one great period
of igneous activity, so that the dacites and grano-diorites of
Macedon, Dandenong and Healesville, in the absence of other
evidence, may be classed as Lower Devonian.

Dr. Howitt (7) has shown that the Snowy River porphyries are
Lower Devonian in age, so that there is a strong probability that
the dacites and Snowy River Porphyries are genetically related.
Unfortunately the Snowy River Porphyries cannot be included in
this discussion, as no analyses of these rocks have been made.

In Central Victoria are numerous occurrences of granite rocks,
and there range from granodiorite through adamellite to normal
granite.

Mr. Stillwell (20) has described the granitic rock of Broadmeadows
as adamellite, and gives an analysis by Mr. H. C. Richards of a
specimen from Gellibrand Hill. Professor Skeats (16) has described
the rock from Mount Eliza, in the Mornington Peninsula, as a
grano-diorite, and gives an analysis of the rock estimated by means
of Rosival's method. The large mass of granitic rocks extending in
a rude semi-circle to the north of Castlemaine and Maldon contains
various types, but that from the Harcourt quarries is on the border
line between the adamellites and granodiorites. An analysis of this
rock was made some few years ago by Mr. G. Ampt, and is given
later.

North-west of Bacchus Marsh, near Ingliston, is an intrusion of
adamellite (provisional name). This has been analysed by Mr. A.
G. Hall at the Mines Department Laboratory, and the analysis will
be given later.

Sections of the granitic rocks near Bulla show that these rocks are at the alkalic end of the granodiorites.

Professor Skeats (17) has described the rock from Station Peak, in the You Yangs, as a granite containing anorthoclase.

Exceedingly similar in the hand specimen and under the microscope to the Station Peak granite, but somewhat finer in grain, is the granite from the Dog Rocks near Geelong.

Microscopical examination shows that the rocks from Cape Woolamai, Gabo Island, and Mt. Buffalo are granites, and are easily distinguishable from the granodiorites of Central Victoria. This difference in the microscopial characters led to the belief that there were two types of granitic rocks in Victoria, which were quite distinct in their chemical characters, and had no genetic relationship with one another. At first sight chemical analyses, to be quoted later, seem to uphold this view. The granodiorites are intruded into both the Ordovician and Silurian sedimentary series, whereas at present no true granitic rocks are known within the Silurian area. This led to the view that whereas the granodiorites were post-Silurian, the granites might possibly be pre-Silurian.

There is no exposed contact between the granites of the You-Yangs or the Dog Rocks with fossiliferous sediments, but there is little doubt that these granites are related to those of Maude, which are intruded into sandstones and slates belonging to the Darriwell horizon of the Lower Ordovician. The Mt. Buffalo granite is in-truded into the Upper Ordovician.

Evidence, however, will be adduced from a study of chemical analyses of some of these rocks to show that the granites and granodiorites are gentically related to one another.

(c) *Lilydale Devonian Series.*

Recently Mr. M. Morris has been working on a series of igneous rocks which occur in the neighbourhood of Lilydale. Analyses of four of the types have been made at the Mines Department Laboratory, and these are of considerable interest owing to their variation from the normal dacites of the Dandenong Ranges, with which they are intimately connected. Mr. Morris has kindly allowed me to use these analyses, but no description of the microscopical characters or field relations can be given here.

(d) *Macedon Kainozoic Series.*

During the Kainozoic Period Victoria was the centre of intense vulcanicity. Extensive flows of basalt covered a considerable area of Southern Victoria, while isolated patches are fairly widely distributed throughout the State.

The early geological survey of Victoria subdivided these basalt rocks into older and newer Volcanic. In some cases where the lavas come into relation with the Kainozoic marine series the age can be fairly definitely fixed, but in a large number of cases field evidence as to exact age is wanting. Professor Skeats (15) has discussed the relative ages of these basalts and has pointed out that '' the reference of a basalt to the older or newer series is frequently based only on conjecture or analogy.''

The basalts of the plains to the north of Melbourne, however, clearly belong to the younger series, as they overlie the Kainozoic marine series at Essendon, Keilor and elsewhere.

The plains are continuous up to the slopes of Mount Macedon, and there is not the slightest doubt that the basalts of the plains near Macedon belong to the newer series.

Somewhat older than these basalts are the interesting series of alkaline rocks which flank the slopes of Mount Macedon.

The alkali rocks which have been recognised in the Macedon District consist of solvsbergite, anorthoclase trachyte, anorthoclase olivine trachyte, olivine anorthoclase trachyte, limburgite, macedonite, woodendite, and anorthoclase basalt. For reason given in the paper on the Macedon District, Professor Skeats and the author consider the probable order of extrusion was :—

1. Anorthoclase trachyte.
2. Solvsbergite.
3. Anorthoclase basalt, Macedonite, Woodendite.
4. Anorthoclase olivine trachyte, Olivine anorthoclase trachyte.
5. Limburgite.

The solvsbergites are in the form of plugs at the Camel's Hump, Hanging Rock and Brock's Monument, while the remaining types occur as more or less widely spread lava flows. The age of these rocks is considered to be probably mid-Kainozoic.

III. Differentiation of the Rocks.

One of the most interesting problems to the petrologist is that of the causes which give rise to the great diversity of types of igneous rocks. As has been stated earlier, the aim in the present paper is rather to show the relationships of the end products than to attempt an explanation of the causes which have led to the production of the various types belonging to any one series.

Harker (4) has shown that the serial relationship of the rocks of any petrographic province may be expressed by means of variation diagrams constructed with the silica percentages of the several

rocks taken as abscissae, and the percentages of the other constituents as ordinates. Such a variation diagram was constructed, based on the analyses of the Macedon granodiorite-dacite series, and is given in Fig. 1.
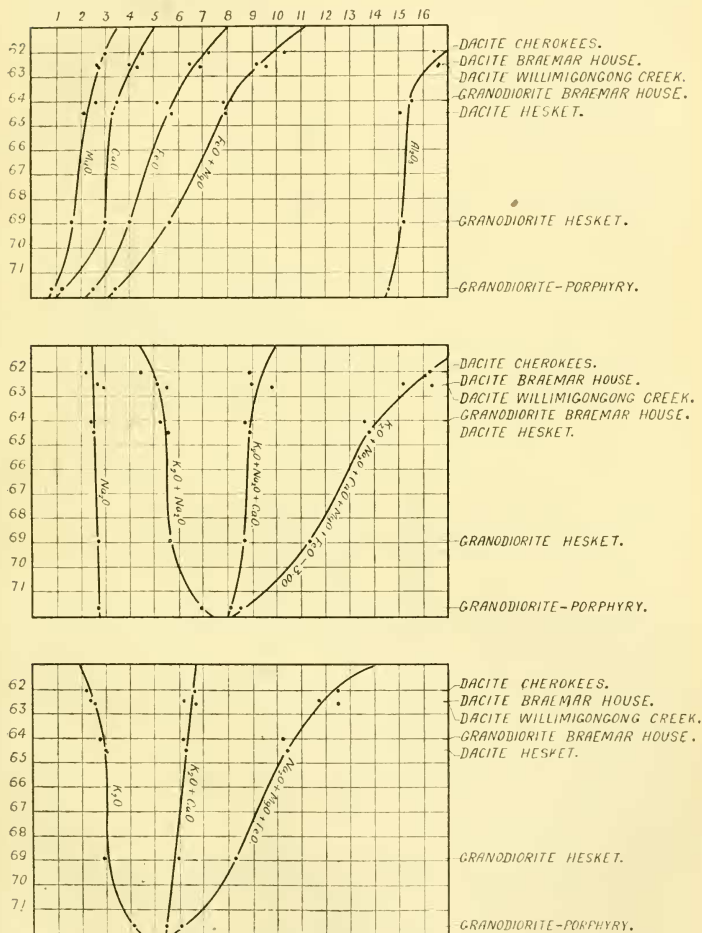

Fig. 1.
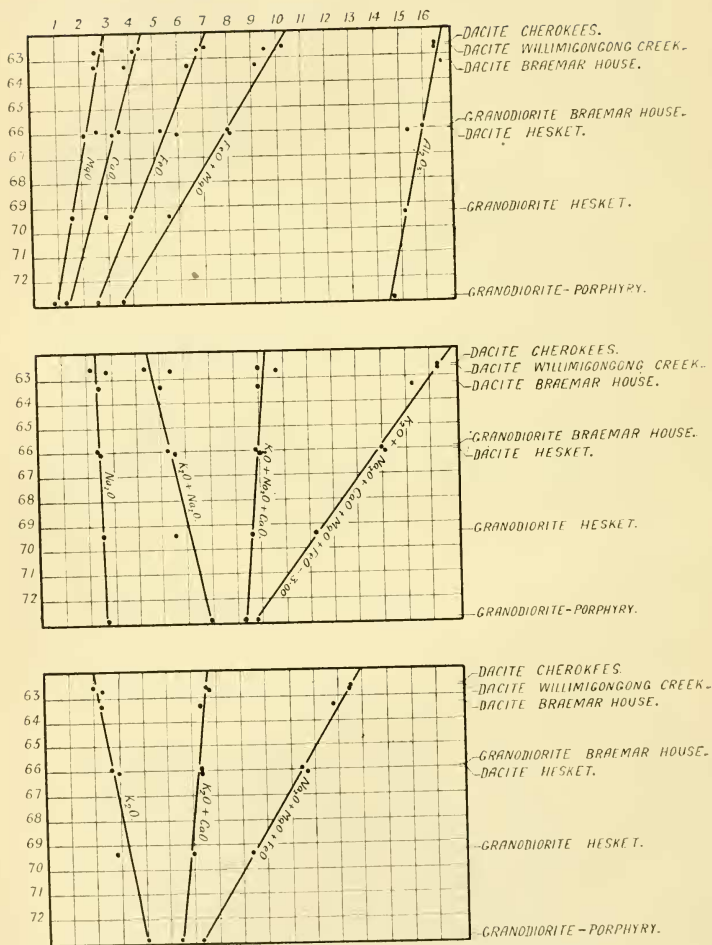
Fig. 2.

As the analyses showed a considerable range in the amount of water, and as the totals varied somewhat, it was felt that the analyses as they stood were not quite comparable with one another, so that the analyses were recalculated to 100 per cent. with the water omitted. Portion of the ferrous oxide originally present in the rocks had been converted to ferric oxide, and as the amount of oxidation varied it was thought better to calculate all the iron as ferrous oxide, and manganous oxide was added to the ferrous oxide.

A second variation diagram based on these recalculated analyses was made, and is given in Fig. 2. The difference between these two diagrams is very marked, as Fig. 1 shows a series of sigmoidal curves, whereas in Fig. 2 the variation is expressed by straight lines. As this second diagram was considered to bring out the relationship of the various types to one another better than was the case in the first diagram, other diagrams used in the paper have been plotted from recalculated analyses.

(a) *The Macedon Granodiorite-Dacite Series.*

Seven analyses of rocks belonging to this series have been made in the Mines Department Laboratory, and these are given in Table I.

TABLE I.

		I.	II.	III.	IV.	V.	VI.	VII.
SiO	-	62.04	62.54	62.56	64.04	64.48	68.92	71.65
Al_2O_3	-	16.50	16.66	16.60	15.58	15.07	15.26	14.56
Fe_2O_3	-	0.66	1.04	1.02	0.80	0.60	0.80	1.13
FeO	-	6.67	5.54	5.98	4.47	5.19	3.30	1.56
MgO	-	3.06	2.68	2.70	2.64	2.17	1.64	0.84
CaO	-	4.56	3.92	4.30	3.52	3.31	3.04	1.27
Na_2O	-	2.27	2.66	2.98	2.42	2.55	2.71	2.76
K_2O	-	2.14	2.47	2.57	2.80	3.04	2.93	4.14
$H_2O +$	-	0.54	0.46	0.68	2.25	2.01	1.04	0.15
$H_2O -$	-	0.16	0.17	0.18	0.38	0.13	0.22	1.20
CO_2	-	nil.	nil.	nil.	nil.	tr.	nil.	nil.
TiO_2	-	1.16	1.20	1.10	0.80	0.90	0.70	0.35
P_2O_5	-	0.19	0.20	0.17	0.18	0.22	0.19	0.12
Mno	-	tr.	tr.	tr.	tr.	0.11	tr.	0.04
Li_2O	-	nil.	tr.	tr.	tr.	tr.	tr.	st. tr.
Cl	-	tr.	tr.	tr.	tr.	tr.	nil.	tr.
NiO	-	—	—	—	—	0.01	.—	nil.
CoO	-	—	—	—	—	0.01	—	nil.
FeS_2	-	nil.	nil.	nil	nil.	—	nil.	—
SO_3	-	—	—	—	—	nil.	—	—
Total	-	99.95	99.54	100.85	99.88	99.79	100.75	99.77
Sp. Gr.	-	7.789	2.781	2.773	2.722	2.708	2.688	2.630

    I.   Dacite, $\frac{3}{4}$ miles south-west of Cherokees.
   II. Dacite, 50 yards south of Braemar House Stable.
  III. Dacite, Willimigongong Creek, Upper Macedon.
  IV. Granodiorite, near Braemar House.
   V. Dacite, 1 mile west of Hesket.
  VI. Granodiorite, near old Sawmill, Hesket.
 VII. Granodiorite, Porphyry, Barringo Creek.

For reasons given above these analyses were recalculated to 100 per cent. with the water omitted, and all the iron reckoned as ferrous oxide. These recalculated analyses are given in Table II., arranged in order of increasing silica percentage :—

TABLE II.

		I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	-	62.59	62.64	63.29	65.90	66.04	69.33	72.88
Al_2O_3	-	16.65	16.62	16.86	16.03	15.46	15.35	14.81
FeO	-	7.26	6.91	6.56	5.35	6.03	4.04	2.67
MgO	-	3.09	2.70	2.71	2.72	2.22	1.65	0.85
CaO	-	4.60	4.30	3.97	3.62	3.39	3.06	1.30
Na_2O	-	2.29	2.99	2.69	2.49	2.61	2.73	2.81
K_2O	-	2.16	2.57	2.50	2.88	3.11	2.95	4.20
TiO_2	-	1.17	1.10	1.22	0.82	0.92	0.70	0.36
P_2O_5	-	0.19	0.17	0.20	0.19	0.22	0.19	0.12
Total	-	100.00	100.00	100.00	100.00	100.00	100.00	100.00

    I.   Dacite, $\frac{3}{4}$ mile south-west of Cherokees.
   II. Dacite, Willimigongong Creek, Upper Macedon.
  III. Dacite, 50 yards south of Braemar House Stable.
  IV. Granodiorite, near Braemar House.
   V. Dacite, 1 mile west of Hesket.
  VI. Granodiorite, near old Sawmill, Hesket.
 VII. Granodiorite porphyry, Barringo Creek.

It will be seen that the only difference in the order of the analyses in the two tables is that the Braemar House and the Willimigongong Creek dacites change places.

As already pointed out, there is a very marked difference in the shape of the graphs in the two variation diagrams plotted from the original and the recalculated analyses respectively. In the second diagram the relationship of the different types to one another agrees with Harker's " linear variation " as the percentage of each oxide is a linear function of the silica percentage.

One interesting point was noted in regard to the recalculated analyses of these dacite and granodiorite, viz., that the sum of the molecular ratios was approximately a constant figure. The molecular ratios of these rocks are given in Table III. :—

TABLE III.

		I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	-	1.043	1.044	1.055	1.098	1.101	1.156	1.215
Al_2O_3	-	.164	.163	.166	.157	.152	.151	.145
FeO	-	.101	.096	.092	.075	.084	.056	.037
MgO	-	.077	.068	.068	.068	.056	.041	.021
CaO	-	.082	.077	.071	.064	.061	.055	.023
Na_2O	-	.037	.048	.044	.040	.042	.044	.045
K_2O	-	.023	.028	.027	.031	.033	.032	.045
TiO_2	-	.015	.014	.015	.010	.011	.009	.005
P_2O_5	-	.001	.001	.001	.001	.001	.001	.001
Total	-	1.543	1.539	1.539	1.544	1.541	1.545	1.537

I. Dacite, Cherokees.
II. Dacite, Willimigiongong Creek.
III. Dacite, Braemar House.
IV. Granodiorite, Braemar House.
V. Dacite, Hesket.
VI. Granodiorite, Hesket.
VII. Granodiorite Porphyry, Barringo Creek.

It must be admitted that these recalculated analyses do not truly represent the composition of the different types, as there is no allowance made for the presence of ferric iron or magmatic water; but still the above result must be considered significant.

If we use the term "unit molecular concentration" to indicate the sum of the molecular ratios, then in the case of the Macedon granodiorite-dacite series the unit molecular concentration remained constant throughout the various stages in the differentiation of these rocks. It will be seen later that there is apparently a relationship between the molecular concentration and the shape of the variation curves.

(b) *Victorian Upper Palaeozoic Series.*

Besides the rocks of the Macedon area, analyses have been made of other dacites, granodiorites, etc., belonging to the Upper Palaeozoic of Victoria.

Several analyses of rocks from the Dandenong and Healesville district were made some years back at the Mines Department Laboratory, but the methods used were such that too much reliance cannot be placed on the results.

In 1908 Mr. H. C. Richards (12) analysed the dacite from near Upwey, in the Dandenong Ranges, and this analysis compares very closely with those of the Macedon dacites.

Thanks to the courtesy of Mr. E. J. Dunn, late Director of the Geological Survey of Victoria, several analyses of granitic rocks

have been made for me at the Mines Department Laboratory.
Excluding the Macedon and Lilydale rocks, all the superior analyses
of the Victorian Lower Palaeozoic igneous rocks are given in Table
IV.

TABLE IV.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
SiO_2 -	63.27	67.75	69.19	70.51	70.94	71.57	72.49	73.30	75.99	76.31
Al_2O_3	16.50	16.11	13.45	14.36	13.99	13.58	13.48	13.84	13.10	13.09
Fe_2O_3	0.68	0.50	2.71	0.33	0.35	1.18	1.16	0.82	0.57	0.41
FeO -	5.10	4.00	2.78	1.95	3.02	2.19	2.09	1.22	0.61	1.07
MgO	2.48	0.79	1.06	1.08	0.80	1.07	0.49	0.82	0.18	0.36
CaO -	4.18	2.68	2.04	2.98	2.35	1.72	1.31	0.84	0.41	0.65
Na_2O	2.36	2.60	2.89	3.17	3.94	2.79	3.38	3.12	3.30	3.00
K_2O +	2.68	3.42	3.94	3.15	3.66	4.36	4.06	4.89	5.27	4.76
H_2O -	0.52	0.96	0.77	1.18	0.21	0.69	0.76	0.50	0.40	0.29
H_2O -	0.09	0.20	0.16	—	0.11	0.11	0.18	0.19	0.14	0.11
CO_2 -	nil.	nil.	0.07	nil.	nil.	0.29	trace	nil.	nil.	0.66
TiO_2 -	1.30	0.85	0.51	1.20	0.58	0.46	0.46	0.20	0.11	0.20
P_2O_5 -	0.15	0.09	0.18	0.12	trace	0.11	trace	0.08	trace	trace
MnO -	0.03	trace	0.14	trace	nil.	0.09	0.13	0.15	0.06	0.11
Li_2O -	trace	—	trace	—	—	st.tr.	trace	nil.	trace	trace
Cl -	—	—	trace	—	—	trace	trace	nil.	trace	trace
NiO -	—	—	—	nil.	0.08	—	nil.	nil.	nil.	0.01
CoO -	—	—	—	nil.	—	—	nil.	nil.	nil.	trace
Cr_2O_3	—	—	—	trace	—	—	—	—	—	—
SO_3 -	—	—	nil.	—	—	nil.	nil.	nil.	nil.	nil.
FeS_2 -	0.16	—	—	—	—	—	—	—	—	—
BaO -	—	—	—	—	—	—	—	—	nil.	—
Total -	99.50	99.95	99.89	100.11	99.95	100.21	99.99	99.97	100.16	100.43
Sp. Gr.	2.76	2.68	2.666	—	—	2.655	2.635	—	2.620	2.643

I.   Dacite, Upwey.1 (Analyst, H. C. Richards.)
II.   Adamellite2, Granite Quarry, Mt. Gellibrand, Broad-
         meadows. (Analyst, H. C. Richards.)
III. Adamellite, Trawool Quarry. (Analyst, A. G. Hall.)
IV.   Hypersthene quartz porphyrite, Road Metal Quarries,
         Violet Town. (Analyst, G. Ampt.)
V.   Granodiorite, Harcourt Quarry. (Analyst, G. Ampt.)
VI.   Adamellite, Ingliston. (Analyst, A. G. Hall.)
VII. Granite, Gabo Island. (Analyst, J. Watson.)
VIII. Granite,3 Mount Buffalo. (Analyst, A. G. Hall.)
IX.   Granite, Dog Rocks, Geelong. (Analyst, A. G. Hall.)
X.   Granite, Cape Woolamai. (Analyst, A. G. Hall.)

These analyses have been recalculated to 100 per cent. with the
total iron converted to ferrous oxide and the water omitted.   Man-

1. Proc. Roy. Soc. Victoria, vol. xxi. (N.S.), Pt. II., 1909, p. 533,
2. Proc. Roy. Soc, Victoria, vol. xxiv. (N.S.), Pt. I., 1911, p. 177.
3. Memoirs of Geol. Surv. of Victoria, No. 6, 1908, p. 8.

ganous oxide is added to the ferrous oxide. These recalculated analyses, together with those of the Macedon Rocks, are given in Table V., arranged in order of increasing silica percentage.

TABLE V.

		I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
SiO_2	-	62.59	62.64	63.29	64.06	65.90	66.04	68.61	69.33	70.17
Al_2O_3	-	16.65	16.62	16.86	16.71	16.03	15.46	16.31	15.35	13.63
FeO	-	7.26	6.91	6.56	5.91	5.35	6.03	4.51	4.04	5.43
MgO	-	3.09	2.70	2.71	2.52	2.72	2.22	0.80	1.65	1.07
CaO	-	4.60	4.30	3.97	4.23	3.62	3.39	2.72	3.06	2.07
Na_2O	-	2.29	2.99	2.69	2.39	2.49	2.61	2.64	2.73	2.93
K_2O	-	2.16	2.57	2.50	2.72	2.88	3.11	3.46	2.95	4.00
TiO_2	-	1.17	1.10	1.22	1.31	0.82	0.92	0.86	0.70	0.52
P_2O_5	-	0.19	0.17	0.20	0.15	0.19	0.22	0.09	0.19	0.18
Total	-	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

		X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
SiO_2	-	70.73	71.24	71.29	72.29	72.88	73.30	73.89	76.34	76.37
Al_2O_3	-	14.08	14.04	14.52	13.72	14.81	13.62	13.95	13.16	13.10
FeO	-	3.90	3.34	2.37	3.37	2.67	3.29	2.13	1.20	1.56
MgO	-	1.08	0.80	1.09	1.08	0.85	0.50	0.83	0.18	0.36
CaO	-	2.54	2.36	3.01	1.74	1.30	1.32	0.85	0.41	0.65
Na_2O	-	3.05	3.96	3.18	2.82	2.81	3.41	3.14	3.31	3.00
K_2O	-	3.61	3.68	3.21	4.41	4.20	4.10	4.93	5.29	4.76
TiO_2	-	0.86	.58	1.21	0.46	0.36	0.46	0.20	0.11	0.20
P_2O_5	-	0.15	tr.	0.12	0.11	0.12	tr.	0.08	tr.	tr.
Total	-	100.00	100.00	100.00	100.00	100.00	100.000	100.00	100.000	100.00

     I. Dacite, Cherokees, Macedon District.
     II. Dacite, Willimigongong Creek, Macedon District.
     III. Dacite, Braemar House, Macedon District.
     IV. Dacite, Upwey, Mount Dandenong District.
     V. Granodiorite, Braemar House, Macedon District.
     VI. Dacite, Hesket, Macedon District.
     VII. Adamellite, Broadmeadows.
     VIII. Granodiorite, Hesket, Macedon District.
     IX. Adamellite, Trawool, Strathbogie District.
     X. Average of Adamellite and Quartz Porphyrite, Strathbogie.
     XI. Granodiorite, Harcourt.
     XII. Quartz-porphyrite, Violet Town, Strathbogie District.
     XIII. Adamellite, Ingliston.
     XIV. Granodiorite porphyry, Barringo Creek, Macedon District
     XV. Granite, Gabo Island.
     XVI. Granite, Mount Buffalo.
     XVII. Granite, Dog Rocks, Geelong.
     XVIII. Granite, Cape Woolamai.
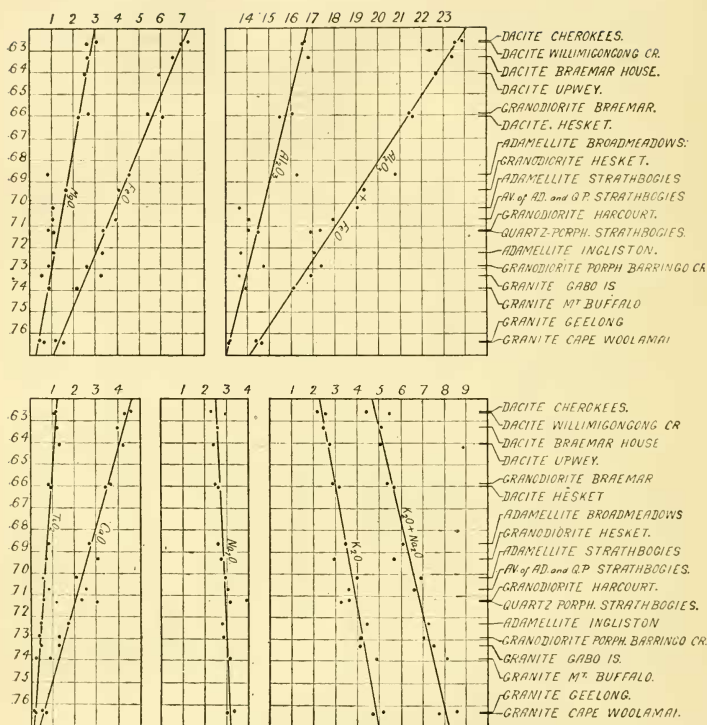
Fig. 3.

A variation diagram has been plotted from these recalculated analyses, and is given in Fig. 3. It will be seen that the variation is of linear type, and that on the whole the various points conform very closely to the graphs. The adamellite from Broadmeadows shows a positive departure in the alumina, and an equal negative departure in the magnesia, while the remaining oxides conform remarkably well. The two rocks from the Strathbogies show decided departures in some cases, but the mean of these two analyses gives points which fall close to the lines. The Harcourt granodiorite shows little departure except in the soda. The four granites conform remarkably well to the graphs.

If variation curves have any real significance, and there seems no doubt that they have, then we must infer that all the rocks whose analyses have been used in the construction of this diagram are genetically related. In this diagram only first-class analyses have been used, and so those of the dacites of Dandenong Ranges and the Black's Spur have been rejected for reason already given.

Analyses by Dr. Howett of quartz-mica-diorites were not included, as titanium oxide had not been estimated and the methods of analysis as used by him were not as exact as those in use at the present day.

The molecular ratios for the different oxides present in the re-calculated analyses and their totals were determined, and it was found that in this case also the total molecular ratios, or using the term suggested earlier, " the unit molecular concentration," remained approximately constant throughout the differentiation. These molecular ratios are given in Table VI.

TABLE VI.

		I.	II.	III	IV.	V.	VI.	VII.	VIII.	IX.
SiO_2	-	1.043	1.044	1.055	1.068	1.098	1.101	1.144	1.156	1.170
Al_2O_3	-	.164	.163	.166	.164	.157	.152	.160	.151	.133
FeO	-	0.101	0.96	.092	.082	.075	.084	.063	.056	.075
MgO	-	.077	.068	.068	.063	.068	.056	.020	.041	.027
CaO	-	.082	.077	.071	.076	.064	.061	0.48	.055	.037
Na_2O	-	.037	.048	.044	.039	.040	.042	.043	.044	.047
K_2O	-	.023	.028	.027	.029	.031	.033	.037	.032	.043
TiO_2	-	.015	.014	.015	.015	.010	.011	.011	.009	.006
P_2O_5	-	.001	.001	.001	.001	.001	.001	.001	.001	.001
Total	-	1.543	1.539	1.539	1.538	1.544	1.541	1.527	1.545	1.539

		X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
SiO_2	-	1.179	1.187	1.188	1.205	1.215	1.222	1.232	1.272	1.273
Al_2O_3	-	.138	.137	.142	.134	.145	.133	.137	.129	.128
FeO	-	.054	.046	.033	.047	.037	.046	.029	.017	.022
MgO	-	.027	.020	.027	.027	.021	.013	.021	.005	.009
CaO	-	.045	.042	.054	.031	.023	.023	.015	.007	.012
Na_2O	-	.049	.064	.052	.045	.045	.055	.051	.053	.048
K_2O	-	.038	.039	.034	.047	.045	.044	.025	.056	.051
TiO_2	-	.011	.008	.015	.006	.005	.006	.003	.001	.003
P_2O5	-	.001	.000	.001	.001	.001	.000	.001	.000	.000
Total	-	1.542	1.543	1.546	1.543	1.537	1.542	1.541	1.540	1.546

If the variation diagram, Fig. 3, can be considered at all a picture of the nature of the differentiation of the magma which produced the various rock types shown, then it is certain that there must be limiting values beyond which differentiation cannot proceed. It is obvious that for any percentage of silica that percentage plus the percentages of the bases as read off on the diagram should in all cases equal one hundred. It follows then that when any line reaches the vanishing point, i.e., the percentage of the oxide represented by that line becomes nil, differentiation as indicated by the diagram must cease. The reason for this statement is that beyond that point the silica percentages plus the percentages of the bases, as indicated on the diagram, must be more than one hundred by the amount (a minus quantity) read off from the vanished line. In order to bring out this point clearly a fresh diagram has been drawn (see Fig. 4).

Two extreme values have been taken to plot the diagram, viz., the mean of the three dacites from Cherokees, Willimigongong Creek and Braemar House, and the mean of the granites from Dog Rocks and Cape Woolamai. The lines have been drawn exactly through these points so that the composition of any possible rock as read off from the diagram may equal one hundred per cent.

The two values used are as under. The molecular ratios are given in the second column in each case.
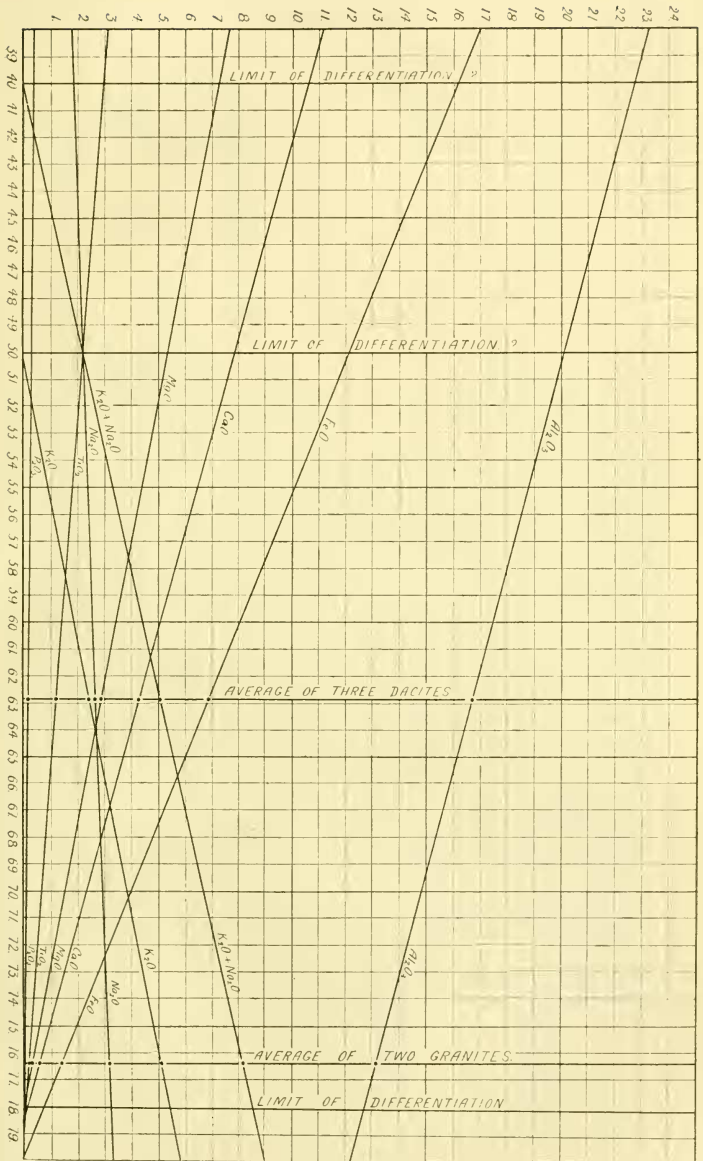
Fig. 4.

		I.		II.	
SiO$_2$	-	62.84	1047	76.36	1273
Al$_2$O$_3$	-	16.71	164	13.13	128
FeO	-	6.91	96	1.38	19
MgO	-	2.82	71	.27	7
CaO	-	4.29	77	.53	10
Na$_2$O	-	2.66	43	3.15	51
K$_2$O	-	2.41	26	5.03	53
TiO$_2$	-	1.16	15	.15	2
P$_2$O$_5$	-	.19	1	tr.	—
Total	-	100.00	1540	100.00	1543

I. Average of analyses of dacite from Cherokees, Willimigongong Creek
and Braemar House.

II. Average of analyses of granite from Dog Rocks, Geelong, and Cape
Woolamai.

The lines drawn through the points representing the percentage
of the oxides are produced both ways. It will be seen that in the
direction of increasing silica percentage the magnesia line vanished
at 78 per cent. silica, and is closely followed by the lime. It is
considered that a rock containing 78 per cent. silica is the most
acid product that this magma could produce under this type of
differentiation. A more acid rock than this could, however, be pro-
duced by a complementary subdivision of one of the possible pro-
ducts of the linear type of differentiation.

In the direction of decreasing silica percentage the potash line
vanished at approximately 50 per cent. silica, and this point is a
possible limit of differentiation in the basic direction. In working
out other variation diagrams it has been found that whereas the
total alkalies may show a linear type of variation the soda and
potash lines may become curved. In this case, then, there is the
possibility that differentiation may not reach a limit until the total
alkalies become nil at about 40 per cent. silica. In reading off any
composition below 50 per cent. the soda line must be disregarded
and the soda read off from the total alkalies line. Compositions
have been read off the diagram for every 5 per cent. increase of
silica, and are given in Table VII., together with the most acid
differentiation product containing 78 per cent. of silica.

TABLE VII.

		I.		II.		III.		IV.	
SiO₂	-	40.0	.667	45.0	.750	50.0	.833	55.0	.917
Al₂O₃	-	22.7	.223	21.4	.210	20.1	.197	18.8	.184
FeO	-	16.2	.225	14.2	.197	12.1	.168	10.1	.140
MgO	-	7.3	.183	6.3	.158	5.3	.133	4.4	.110
CaO	-	10.6	.189	9.3	.166	7.8	.139	6.5	.116
Na₂O	-	0.0	.000	1.0	.016	2.2	.033	2.4	0.39
K₂O	-	0.0	.000	0.0	.000	0.0	.000	0.8	.009
TiO₂	-	2.9	.036	2.5	.031	2.2	.028	1.8	.023
P₂O₅	-	0.3	.022	0.3	.002	0.3	.002	0.2	.001
Total	-	100.0	1.525	100.0	1.530	100.0	1.535	100.0	1.593

		V.		VI.		VII.		VIII.		IX.	
SiO₂		60.0	1.000	65.0	1.083	70.0	1.169	75.0	1.250	78.0	1.300
Al₂O₃	-	17.5	.172	16.1	.158	14.8	.145	13.2	.132	12.6	.124
FeO	-	8.0	.111	6.0	.083	4.0	.056	1.9	.026	0.7	.010
MgO	-	3.4	.085	2.5	.063	1.5	.038	0.5	.013	0.0	.000
CaO	-	5.1	.091	3.7	.066	2.3	.041	0.9	.016	0.1	.002
Na₂O	-	2.6	.042	2.7	.044	2.9	.047	3.1	.050	3.2	.052
K₂O	-	1.8	.019	2.8	.030	3.8	.040	4.8	.051	5.4	.057
TiO₂	-	1.4	.018	1.0	.013	0.6	.008	0.3	.004	0.0	.000
P₂O₅	-	0.2	.001	0.2	.001	0.1	.001	0.0	.000	0.0	.000
Total	-	100.0	1.539	100.0	1.541	100.0	1.543	100.0	1.542	100.0	1.545

Naturally the most interesting compositions are those of the limiting members of the series. Taking the acid limit first, we find that such a composition would give practically pure quartz and felspar, as may be seen from the following :—

TABLE VIII.

		Percent-age.	Molecular Ratios.	Ortho-clase.	Albite.	Anor-thite.	Quartz.	Remainder.
SiO₂	-	78.0	1.300	342	312	4	642	—
Al₂O₃	-	12.6	.124	57	52	2	—	.013
FeO	-	0.7	.010	—	—	—	—	.010
MgO	-	0.0	.000	—	—	—	—	—
CaO	-	0.1	.002	—	—	2	—	—
Na₂O	-	3.2	.052	—	52	—	—	—
K₂O	-	5.4	.057	57	—	—	—	—

Quartz	-	.642 × 60	=	38.52
Orthoclase	-	.057 × 556	=	31.69
Albite	-	.052 × 524	=	27.25
Anorthite	-	.002 × 278	=	.56
				98.02

The FeO may be assumed to be present as magnetite, as the percentage of FeO also includes the Fe_2O_3, and the small amount of alumina is negligible considering the data on which the estimation is made. It would seem then that the acid limit product of the differentiation would be a rock consisting of approximately 38.5 per cent. free quartz and 59.5 per cent. felspar. In the case of the more acid of the hypothetical limits of differentiation in the direction of decrease of silica the composition may be estimated as follows :—

TABLE IX.

		Percentage.	Molecular Ratios.	Ilmenite.	Apatite.	Albite.	Anorthite.	Remainder.
SiO_2	-	50.0	.833	—	—	198	266	369
Al_2O_3	-	20.1	.197	—	—	33	133	31
FeO	-	12.1	.168	28	—	—	—	140
MgO	-	5.3	.133	—	—	—	—	133
CaO	-	7.8	.139	—	6	—	133	—
Na_2O	-	2.2	.033	—	—	33	—	—
K_2O	-	0.0	.000	—	—	—	—	—
TiO_2	-	2.2	.028	28	—	—	—	—
P_2O_5	-	0.3	.002	—	2	—	—	—

It will be seen that there is more than sufficient silica left after the production of felspar to form a metasilicate of magnesia, ferrous iron and alumina. This excess of silica would be actually greater, as portion of the iron would go to form magnetite. If we allowed an equal amount of ferrous oxide for magnetite, as was required for ilmenite, viz., 28 parts, this would reduce the amount of ferrous iron by 84 points, and a possible composition of the hypothetical rock would be as under :—

$$
\begin{aligned}
&\text{Quartz} & & .149 \times 60 & &= 8.94 \\
&\text{Plagioclase} & & \left\{ \begin{array}{l} .033 \times 524 = 17.29 \\ .133 \times 278 = 36\,97 \end{array} \right\} & &= 54.26 \\
&\text{Ilmenite} & & .028 \times 152 & &= 4.26 \\
&\text{Magnetite} & & .028 \times 232 & &= 6.50 \\
&\text{Apatite} & & .002 \times 336 & &= .67 \\
&\text{Aluminous Amphibole} & & \left\{ \begin{array}{l} .031 \times 162 = 5.02 \\ .133 \times 100 = 13.30 \\ .036 \times 132 = 7.39 \end{array} \right\} & &= 25.71 \\
& & & & & \overline{100.34}
\end{aligned}
$$

It will be seen that the rock would consist essentially of plagioclase and an aluminous amphibole or pyroxene with some quartz and a moderate amount of iron minerals.

Turing now to the more basic hypothetical limit of possible differentiation, the composition of the rock may be estimated in a similar manner, an equal amount of ferrous iron being allowed for magnetite as is required for ilmenite.

TABLE X.

		Percentage.	Molecular Ratios.	Apatite.	Ilmenite.	Magnetite.	Anorthite.	Aluminous Amphibole.	Remainder.
SiO_2	-	40.0	.667	—	—	—	366	304	-3
Al_2O_3	-	22.7	.223	—	—	—	183	40	—
Fe_2O_3	-	—	—	—	—	36	—	—	—
FeO	-	16.2	.225	—	36	36	—	81	—
MgO	-	7.3	.183	—	—	—	—	183	—
CaO	-	10.6	.189	6	—	—	183	—	—
Na_2O	-	0.0	.000	—	—	—	—	—	—
K_2O	-	0.0	.000	—	—	—	—	—	—
TiO_2	-	2.9	.036	—	36	—	—	—	—
P_2O_5	-	0.3	.002	2	—	—	—	—	—

Anorthite -   -   - $.183 \times 278$ $= 50.87$

Aluminous* Amphibole $\left\{ \begin{array}{l} .040 \times 162 = 6.48 \\ .081 \times 132 = 10.69 \\ .183 \times 100 = 18.30 \end{array} \right\} = 35.47$

Magnetite   -   - $.036 \times 232$ $= 8.35$

Ilmenite   -   -   - $.036 \times 152$ $= 5.47$

Apatite   -   -   - $.002 \times 336$ $= .67$

This composition seems a rather more rational end point than the other, as the rock would consist essentially of two minerals, anorthite and aluminous amphibole or pyroxene.

It is interesting to note that the ratio of the quartz to felspar is 39.3; 60.7 in the case of the acid limiting value, and that the ratio of the pyroxene to felspar in the case of the basic limit is approximately the same, viz., 41.1; 58.9.

While suggesting that these two values as read off from the diagram represent the theoretical limits of this linear differentiation, it does not follow that rocks with such composition would necessarily separate out from the given magma. In actual occurrence the composition of the original undifferentiated parent magma must be a controlling factor in limiting differentiation.

(c) *Macedon Kainozoic Alkali Series.*

All the leading types of rocks belonging to this series have been analysed at the Mines Department Laboratory, and in all nineteen first-class analyses have been made. These are given in Table XI.

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* This is not a true metasilicate as the Al_2O_3 and SiO_2 are combined in the proportion 1 : 1, but an examination of a number of analyses of aluminous amphiboles and pyroxenes shows that generally silica must be allotted to alumina in the above proportion.

TABLE XI.

	I.	II.	III.	IV.	V.	V.	VII.	VIII.	IX.	X.
SiO_2 -	43.06	43.24	43.58	43.82	45.10	47.02	48.83	50.14	51.48	51.52
Al_2O_3 -	13.06	13.19	11.46	12.90	12.86	12.52	16.69	16.91	16.34	16.58
Fe_2O_3 -	4.68	4.42	3.40	6.74	5.66	5.81	2.66	3.26	4.86	2.35
FeO -	8.10	8.46	9.13	6.25	7.10	5.83	8.40	9.15	5.14	7.68
MgO -	9.92	8.48	10.80	9.32	8.56	9.92	5.56	2.62	2.82	4.03
CaO -	9.30	9.32	9.88	9.44	9.10	8.38	7.95	5.18	4.70	6.10
Na_2O -	2.14	2.28	2.18	2.49	3.99	3.23	2.92	3.80	3.57	4.11
K_2O -	2.14	1.68	2.13	1.75	1.02	3.23	2.10	2.78	3.43	2.99
H_2O + -	2.53	2.46	2.40	1.70	1.53	0.70	0.66	2.16	1.62	0.22
H_2O - -	0.76	2.03	0.47	1.26	1.10	0.69	1.34	0.14	1.90	1.39
CO_2 -	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
TiO_2 -	3.60	3.15	3.32	3.50	3.50	2.60	2.85	1.90	2.62	2.15
P_2O_5 -	0.96	1.13	0.95	1.02	1.00	1.23	0.74	1.19	1.28	0.82
Mno -	0.43	0.18	trace	0.37	0.08	0.12	0.25	0.38	0.35	0.13
Li_2O -	nil.	nil.	nil.	nil.	nil.	nil.	nil.	nil.	nil.	st.tr.
Cl -	trace	trace	trace	trace	trace	trace	0.04	trace	trace	0.05
NiO ⎱ CoO ⎰ -	—	—	—	—	—	—	—	—	nil.	0.06
SO_3 -	nil.	nil.	nil.	nil.	nil.	nil.	trace	nil.	nil.	nil.
Total -	100.68	100.02	99.70	100.56	100.60	100.28	100.99	99.61	100.11	100.18
Sp. Gr. -	2.935	2.901	2.995	2.995	2.854	2.888	2.870	2.786	2.760	2.787

	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.
SiO_2 -	51.72	54.06	59.44	59.52	60.10.	62.56	65.46	66.86	67.06
Al_2O_3 -	13.36	17.13	17.98	18.06	18.38	17.89	17.40	16.34	17.40
Fe_2O_3 -	2.80	6.10	2.28	3.76	2.22	4.98	3.00	2.38	2.24
FeO -	8.16	3.55	3.34	2.27	3.34	0.45	1.60	1.99	0.84
MgO -	7.20	3.05	0.78	0.78	1.30	0.18	0.09	0.22	0.26
CaO -	7.68	4.88	2.32	1.98	2.28	0.72	0.76	0.92	0.34
Na_2O -	2.87	3.97	5.36	5.38	5.30	5.06	6.51	6.01	5.88
K_2O -	1.34	3.29	4.77	5.03	4.57	5.13	4.74	4.07	4.10
H_2O + -	0.96	1.00	1.57	0.96	0.43	0.73	0.35	0.41	0.62
H_2O - -	1.61	0.80	0.70	0.88	0.96	1.30	0.52	0.18	0.71
CO_2 -	n.d	nil.	n.d.	n.d.	trace	n.d.	n.d.	n.d.	n.d.
TiO_2 -	2.30	1.95	0.79	0.67	0.69	0.38	0.24	0.21	0.16
P_2O_5	0.25	0.48	0.30	0.27	0.33	0.11	nil.	trace	trace
Mno -	trace	0.20	trace	trace	nil.	trace	trace	trace	trace
Li_2O -	nil.	trace	trace	trace	trace	trace	nil.	trace	trace
Cl -	trace	trace	trace	trace	nil.	nil.	trace	trace	trace
NiO ⎱ CoO ⎰ -	—	0.3	—	—	—	—	—	—	—
SO_3 -	nil.	nil.	nil.	nil.	trace	trace	nil.	nil.	nil.
Total -	100.25	100.71	99.63	99.56	99.90	99.49	100.67	99.59	99.61
Sp. Gr. -	2.828	2.722	2.590	2.621	2.651	2.504	2.596	2.646	2.559

I. Limburgite, lower portion of King's Quarry.
II. Limburgite, No. 1 Quarry, Woodend.
III. Limburgite, No. 4 Quarry, Woodend.
IV. Limburgite, upper portion of King's Quarry.
V. Limburgite, No. 3 Quarry, Woodend.
VI. Woodendite, Old Racecourse Hill, Woodend.
VII. Anorthoclase Basalt, base of Sugarloaf Hill, N.N.E. of Woodend.
VIII. Macedonite, Emu Creek, Macedon District.
IX. Macedonite, Spring Mound, S.S.E. of Lancefield.
X. Olivine anorthoclase trachyte, Parish of Cobaw.
XI. Anorthoclase basalt, quarry at road corner N.N.E. of the Jim Jim.
XII. Anorthoclase olivine trachyte, summit of Sugarloaf Hill.
XIII. Anorthoclase trachyte, Quarry, Parish of Newham.
XIV. Anorthoclase trachyte, Turritable Fall, Upper Macedon.
XV. Anothoclase trachyte, eastern slope of Mount Eliza.
XVI. Anothoclase trachtye, McAlister's Rock, Parish of Newham.
XVII. Solvsbergite, Camel's Hump.
XVIII. Solvsbergite, Brock's Monument.
XIX. Solvsbergite, Hanging Rock.

As in the previous cases these analyses have been recalculated to
100 per cent., but where several analyses are extremely similar to
one another the mean value is taken. Certain blends of analyses
are also included.

TABLE XII.

		1.	2.	3.	4.	5.	6.	7.
SiO_2	-	45.31	47.78	49.48	51.66	51.69	51.84	52.44
Al_2O_3	-	13.15	12.73	16.92	17.43	16.13	16.21	16.87
FeO	-	12.95	10.45	11.19	12.84	11.07	10.91	10.15
MgO	-	9.74	10.08	5.63	2.71	5.06	4.97	4.10
CaO	-	9.74	8.51	8.05	5.35	6.55	6.47	6.21
Na_2O	-	2.71	3.28	2.96	3.93	3.29	3.40	4.18
K_2O	-	1.81	3.28	2.13	2.87	2.62	2.69	3.04
TiO_2	-	3.54	2.64	2.89	1.97	2.68	2.61	2.18
P_2O_5	-	1.05	1.25	0.75	1.24	0.91	0.90	0.83
Total	-	100.00	100.00	100.0	100.00	100.00	100.00	

		8.	9.	10.	11.	12.	13.	
SiO_2		53.08	53.56	54.98	58.03	62.00	67.28	
Al_2O_3	-	13.72	17.01	17.42	17.93	18.54	17.29	
FeO	-	10.97	10.27	9.12	7.33	5.47	3.80	
MgO	-	7.39	2.93	3.10	2.29	0.78	0.19	
CaO	-	7.89	4.90	4.96	3.63	1.87	0.68	
Na_2O	-	2.95	3.71	4.04	4.78	5.42	6.24	
K_2O	-	1.38	3.57	3.35	4.16	5.01	4.36	
TiO_2	-	2.36	2.72	1.98	1.35	0.65	0.20	
P_2O_5	-	0.26	1.33	0.75	0.50	0.26	tr.	
Total	-	100.00	100.00	100.00	100.00	100.00	100.00	

1. Limburgite - Average of 5 analyses.
2. Woodenite - (Complementary).
3. Anorthoclase Basalt - (Complementary).
4. Macedonite - (Complementary)
5. Blend of Complementary Types.
6. Blend of Alkali types less acid Trachyte and Solvsbergite.
7. Olivine anorthoclase Trachyte (Cobaw Type)
8. Anothoclase Basalt - (Complementary).
9. Macedonite - (Complementary).
10. Anorthoclase Olivine Trachyte - (Sugarloaf Type).
11. Blend of Alkali Rocks.
12. Anorthoclase Trachyte - Average of 4 analyses.
13. Solvsbergite - Average of 3 analyses.

Variation diagrams based on these recalculated analyses are given in Fig. 5. The curves obtained are in general better than those plotted from the original analyses (compare with Plates VII.-IX., Bulletin No. 24, Geol. Surv. of Victoria 1912).

The differentiation of the Kainozoic alkali lavas of Macedon has been discussed in some detail (19), but some additions to this discussion may be included here.

In the first place, judging from the variation diagram (Fig. 4), differentiation must have proceeded on different lines to those exhibited by the dacite-granitic series. In the latter case variation could be expressed by straight lines, but the variation of the alkali rocks must be expressed by curves. It has been pointed out above that the molecular concentration of the Palaeozoic rocks remained constant throughout the differentiation.

In the case of the rocks under consideration, however, this is not the case. The molecular ratios are set out in Table XIII., the order of the analyses being the same as in the preceding table.

TABLE XIII.

		1.	2.	3.	4.	5.	6.	7.
SiO_2	-	.755	.796	.825	.861	.862	.864	.874
Al_2O_3	-	.129	.125	.166	.171	.158	.159	.166
FeO	-	.180	.145	.156	.178	.154	.151	.141
MgO	-	.244	.252	.141	.068	.127	.124	.103
CaO	-	.174	.152	.144	.096	.117	.115	.111
Na_2O	-	.044	.053	.048	.064	.053	.055	.068
K_2O	-	.019	.035	.022	.031	.028	.029	.032
TiO_2	-	.044	.033	.36	.025	.034	.033	.027
P_2O_5	-	.008	.099	.006	.008	.006	.006	.006
Total	-	1.597	1.600	1.544	1.502	1.539	1.536	1.628
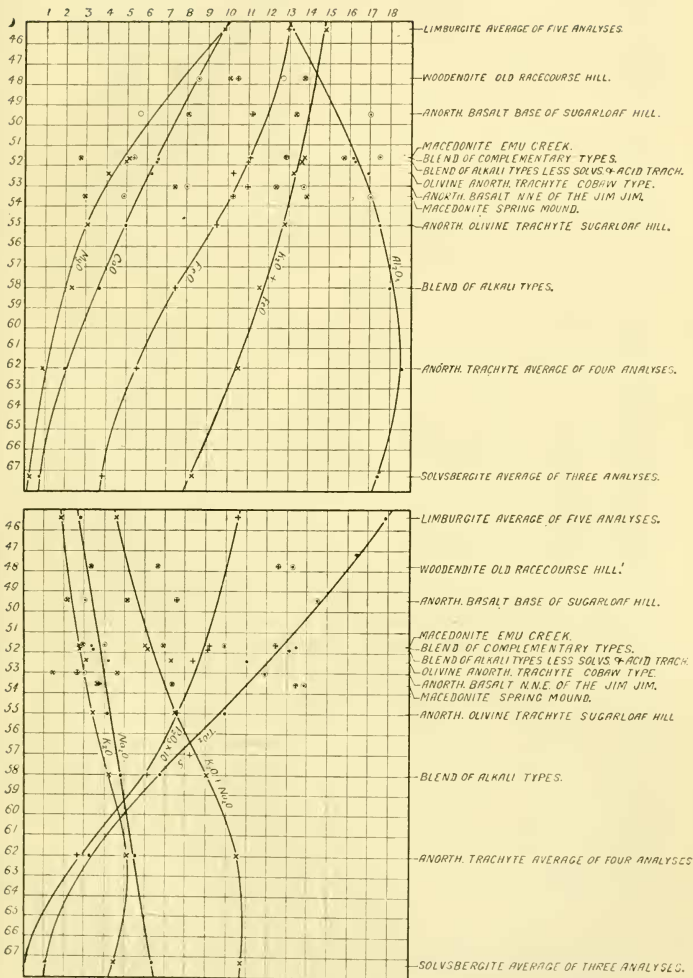
Fig. 5.

TABLE XIII. *(Continued).*

		8.	9.	10.	11.	12.	13.
SiO$_2$	-	.885	.893	.916	.967	1.033	1.121
Al$_2$O$_3$	-	.134	.167	.171	.175	.181	.170
FeO	-	.152	.143	.131	.102	.076	.053
MgO	-	.185	.073	.078	.057	.020	.005
CaO	-	.141	.088	.089	.065	.033	.012
Na$_2$O	-	.048	.060	.065	.077	.087	.101
K$_2$O	-	.015	.038	.036	.045	.053	0.47
TiO$_2$	-	.030	.034	.025	.017	.008	.003
P$_2$O$_5$	-	.002	.009	.006	.004	.002	—
Total	-	1.592	1.505	1.517	1.509	1.493	1.512
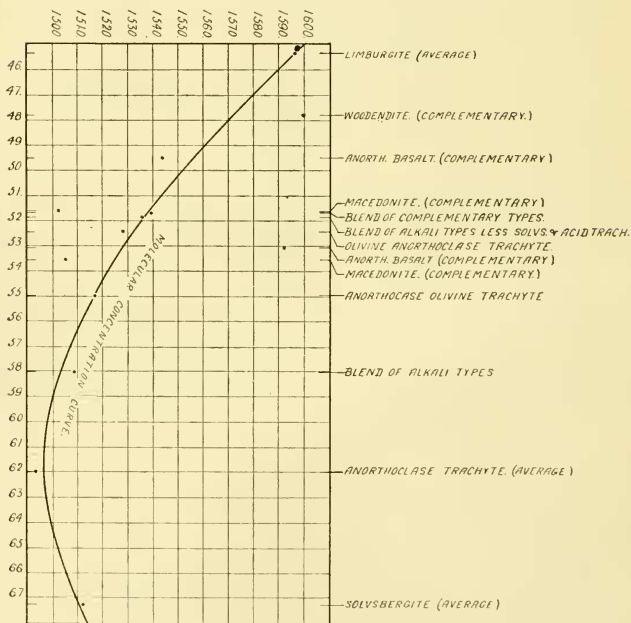
Fig. 6.

The molecular concentration of these analyses has been plotted
and is given in Fig. 6. It will be noted that whereas the normal
rocks of the series conform very closely to the curve, those rocks
which have been described as complementary in origin depart

widely from the curve, but that the blend of the analyses of these rocks agrees closely with the curve.

In dealing with the differentiation of the Macedon alkali series the assumption was made that as the lavas had in general been poured over a fairly level plain, that their bulk would be approximately proportional to the areas occupied by them.

Working on the above assumption the average composition of the alkali rocks was determined, and is given as No. 11 in Tables XII. and XIII.

After the extrusion of the more acid types it was estimated that the composition of the residual magma would be approximately that given as No. 6 in Tables XII. and XIII.

It will be seen that this composition agrees very closely with that obtained by blending the so-called complementary types in proportion to area, and also with that of the anorthoclase olivine trachyte from Sugarloaf Hill. This suggests that after the extrusion of the solvsbergite and acid trachyte the residual magma split into two parts of similar composition, one of which gave rise to the anorthoclase olivine trachyte and limburgite, and the other portion split up to form the macedonite, woodendite and anorthoclase basalt.

It has been suggested that the differentiation of the alkali rocks may be subdivided into two forms—(1) Serial Differentiation, (2) Complementary Differentiation. To the Serial differentiation are assigned those types which conform to the curves, and which show a regular gradation in the percentage of the various constituent oxides. The remaining types show no such regularity in their variation, but appear to have been produced by an irregular subdivision of a partial magma, and consequently are considered to have been derived by complementary differentiation.

The serial differentiation of these alkali rocks may conveniently be referred to as curvilinear serial.

The probable limiting values of the curvilinear type of serial differentiation cannot be determined sufficiently accurately to be of any value, owing to the difficulty of satisfactorily producing the curves, but judging from the norms of the solvsbergites and limburgites the acid limit value would be composed of quartz and anorthoclase, and the basic limit value of anorthite and olivine with a concentration of magnetite, ilmenite and apatite.

The relationship of the Macedon alkali series to other Victorian alkali rocks and to the Newer Basalts has been discussed elsewhere (19). It was pointed out that the alkali lavas and the basaltic lavas in the Macedon area occur in such close juxtaposition and were

almost contemporaneous, so that the assumption that the alkali
series and the basaltic series were derived from two separate and
distinct magmas is hardly tenable. The conclusions may be cited :

" The authors believe that the Kainozoic volcanic rocks of Victoria
were derived from a common magma. First came the separation
and pouring out of the Older Basalts of the eastern and central
portions of Victoria. This left a magma moderately rich in
alkalies, and by some process of differentiation alkali magmas sepa-
rated out into at least three lesser magma basins, viz., at Omeo,
Macedon and Coleraine. On the exhaustion of these lesser magma
basins, extrusion once more took place from the main reservoir,
giving the Newer Basalt series."

It will be seen that the primary differentiation of the Macedon
rocks is considered to have been the separation of the alkali magma
from the basaltic magma, and that secondary differentiation of the
serial and complementary types then ensued, and produced the
various members of the alkali series.

(d) *Lilydale Devonian Series.*

As stated earlier, four analyses of rocks from the Lilydale area
have been made at the Mines Department Laboratory, and these are
given in Table XIV.

TABLE XIV.

		I.	II.	III.	IV.
SiO_2	-	65.83	68.19	68.73	69.93
Al_2O_3	-	14.89	14.98	13.16	15.14
Fe_2O_3	-	0.73	0.74	1.17	1.30
FeO	-	4.63	2.74	2.74	2.33
MgO	-	1.88	.029	1.22	0.26
CaO	-	3.13	1.95	3.03	1.80
Na_2O	-	2.12	3.34	2.30	3.36
K_2O	-	2.34	3.64	2.59	3.55
$H_2O +$	-	2.41	1.40	1.86	0.83
H_2O-	-	0.17	0.14	0.09	0.07
CO_2	-	0.47	1.93	1.50	nil.
TiO_2	-	0.89	0.20	0.50	0.20
P_2O_5	-	0.16	0.05	0.17	0.03
Cr_2O_3	-	trace	nil.	nil.	nil.
Mro	-	0.10	0.08	0.09	0.05
NiO	-	0.01	nil.	0.01	nil.
CoO	-	nil.	nil.	nil.	nil.
BaO	-	0.13	0.27	0.20	0.30
Li_2O	-	nil.	nil.	tr.	tr.
S	-	0.10	tr.	0.18	tr.
SO_3	-	nil.	nil.	nil.	nil.
Cl	-	tr.	tr.	tr.	tr.
Total	-	99.97	99.94	99.54	99.15
Less = S	-	.04	--	.07	--
Total	-	99.93	99.94	99.47	99.15

I.   Dante, Dandenong Range.
II. Toscanite, Quarry 1 m. N.E. of Lilydale.
III. Dacite, Railway Cutting between Lilydale and Evelyn.
IV. Toscanite, about 1 m. E. of Mooroolbark.

The four analyses have been recalculated to 100 per cent., as in the case of previous analyses, and the results, together with the molecular ratios, are given in Table XV.

TABLE XV.

		I.		II.		III.		IV.	
SiO_2	-	68.01	1.134	70.76	1.179	71.30	1.188	71.76	1.196
Al_2O_3	-	15.39	.151	15.54	.152	15.43	.151	13.74	.134
FeO	-	5.58	.078	3.62	.050	3.61	.050	4.06	.057
MgO	-	1.95	.049	0.30	.007	0.26	.006	1.27	.032
CaO	-	3.38	.061	2.29	.041	2.14	.038	3.37	.060
Na_2O	-	2.19	.035	3.46	.056	3.42	.055	2.40	.039
K_2O	-	2.40	.023	3.77	.040	3.61	.036	2.70	.026
TiO_2	-	0.93	.011	0.21	.003	0.20	.003	0.52	.006
P_2O_5	-	0.17	.001	0.05	.000	0.03	.000	0.18	.001
Total	-	100.00	1.543	100.00	1.528	100.00	1.527	100.00	1.551

It is found that these analyses do not conform to the lines of variation of the dacite-granitic series, as shown in Fig. 3, or in the generalised diagram, Fig. 4. The unit molecular concentrations of three of the rocks show distinct departures from the mean concentration of the dacite-granitic series, viz., 1.541. In the case of the Macedon alkali rocks it has been seen that those rocks whose unit concentration departed from the normal variation for the series were probably derived by complementary differentiation. This suggests the possibility that these Lilydale rocks may have been produced by a similar form of differentiation. In this case there is an absence of quantitative data such as was available in the case of the Macedon rocks, and so no direct method is available for determining the relative proportions of the rocks. It is possible that an approximation to the truth may be obtained by combining the analyses in such proportions that the total molecular ratios of the resultant composition may be about equal to the mean molecular concentration of the granite dacites series, viz., 1.541. This result will be obtained by combining the analyses in the proportion of one part of each of the Analyses I., II. and III., and two parts of Analyses IV. One part each of Analyses I. and III., and two parts of Analyses II., and three parts of Analyses IV. will also give approximately the same molecular total.

TABLE XVI.

		I.		II.		III.	
SiO₂	-	70.72	1.175	70.87	1.181	70.8	1.180
Al₂O₃	-	14.77	.145	14.73	.144	14.5	.142
FeO	-	4.18	.058	4.09	.057	3.6	.050
MgO	-	1.01	.025	0.95	.024	1.4	.035
CaO	-	2.91	.052	2.89	.052	2.1	.038
Na₂O	-	2.77	.045	2.82	.045	2.9	.047
K₂O	-	3.04	.032	3.09	.033	4.0	.043
TiO₂	-	.48	.006	0.44	.006	.6	.008
P₂O₅	-	.12	.001	0.12	.001	.1	.001
Total	-	100.00	1.539	100.00	1.543	100.0	1.544

I.   Blend of Lilydale Rocks in the proportion of one part each of 1., II.,
     and III., and two parts of IV.
II. Blend of Lilydale Rocks in the proportion of one part each of I. and
     III., and two parts of II., and three parts of IV.
III. Composition read off from diagram (Fig. 4).   .

It will be seen that these two blends agree fairly closely with the
composition as read off from Fig. 4, and, furthermore, these two
blends conform fairly well to the variation of the dacite-granitic
series. Therefore there seems some justification in concluding that
these Lilydale rocks may have been derived from the common stock
magma of the dacite-granitic series, but that they have been evolved
by complementary differentiation.

IV. Relationships of Igneous Rocks to Earth movements in Victoria.

In his Natural History of Igneous Rocks (4) Harker lays great
stress on the apparent regional distribution of the so-called alkali
and calcic rocks. He considers that the areas occupied by the
alkali and sub-alkali groups correspond respectively with the areas
of the Atlantic and Pacific types of coast line, as defined by Suess
(21). Accordingly the names Atlantic and Pacific Branches of
Igneous Rocks were suggested, but in a later publication (5) Harker
seems to favour the terms Alkali and Calcic Branches.

It is proposed to discuss the relationship of some Victorian rocks
to earth movements in order to see whether the Victorian evidence
is in accord or not with Harker's generalisation. The rocks to be
discussed are the Heathcotian diabases, the granites and dacites of
the Upper Palaezoic and the Kainozoic basalts and alkali rocks.

(a) *Heathcotian Diabases.*

The diabases of Heathcote have been fully described by Dr. Howitt (8), Professor Gregory (3) and Professor Skeats (4), and the age of these rocks and similar types at Lancefield is now generally accepted as being between Middle Cambrian and basal Lower Ordovician. The Lower Ordovician rocks only occur at the surface to the west of the Heathcote-Lancefield line, except in the Mornington Peninsula, and Professor Gregory considered that the area in central Victoria now occupied by Silurian sediments was land surface during the deposition of the Ordovician Rocks, and that the Heathcote-Lancefield line represented the eastern limit of the Lower Ordovician.

Professor Skeats has shown that the cherts and diabases are interbedded, and that the former pass out conformably into normal sediments. The cherts have been shown to be due, at least in part, to the silification of stratified ash, and the inference is that this ash was either derived from submarine volcanoes or from a series of shore line volcanoes.

In the former case marine conditions must have extended eastward of this Heathcote-Lancefield line, and Lower Ordovician rocks should underlie the Silurian. If the latter supposition be correct, then this line may well represent the eastern limit of deposition. At present there is no positive evidence in favour of either of these views, but some negative evidence in favour of the latter, viz., the absence in this locality of known occurrences of Lower Ordovician sediments to the east of Heathcote, but the thick covering of Silurian rocks would completely mask any possible outcrop, so that this evidence is of very little value.

In either case, however, these eruptions of basic lava are more easily explained as accompanying fault action rather than fold action. The linear arrangement of the diabase in a north and south direction, giving rise to the Colbinabbin Range, suggests distribution along a fault line. Another possible explanation is that the linear arrangement is entirely due to the diabases and cherts occurring along the upper portion of an anticline.

Along the western limit of the outcrops in Victoria of Lower Ordovician sediments similar associations of diabases and cherts are found at Mount Stavely and at the Hummocks to the north of Casterton. The simplest explanation is that the Lower Ordovician marine transgression was caused by subsidence between two fault lines, i.e., the earth movements were of the Atlantic coast type. Movements of the Pacific coast type can give rise to a linear arrangement of the associated volcanoes, as evidenced in the great

chain of the Andes, but it is difficult to imagine such earth move-
ments giving the requisite conditions for the production of inter-
bedded submarine lavas and tuffs. While the evidence is not at
all conclusive, I believe that the basic lavas of the Lower Ordovician
were associated with fault movements and, according to Harker's
generalisation, should show alkaline affinities.

(b) *Upper Palaeozoic Series.*

The intrusion of the granites and granodiorites and the associ-
ated volcanic rocks are undoubtedly associated with the intense
earth movements to which the Ordovician and Silurian formations
have been subjected. In the Macedon District (19) we have
evidence of extensive earth movements subsequent to the deposition
of the Lower Ordovician and prior to the deposition of the Upper
Ordovician. The Kerrie Conglomerates have been shown to belong
to the Upper Ordovician, and there is apparently a strong uncon-
formity between these conglomerates and the underlying Lower
Ordovician. The base of the Silurian is also marked by basal con-
glomerates, and the rocks of this system are in general less
folded that those of the Upper Ordovician, so we may fairly safely
infer considerable earth movements as marking the break between
these two great periods of sedimentation. In the eastern part of
Victoria Dr. Howitt (9) has shown that the Lower Devonian was a
period of great igneous activity associated with intense earth
folding. The Mansfield sandstones of Upper Devonian or Lower
Carboniferous age rest unconformably on the upturned edges of
the Silurian.

Folding over north and south axes was the prevailing type of
tectonic movement to which the Ordovician and Silurian sediments
were subjected, so that we can safely infer that the granites, grano-
diorites, dacites, etc., were associated with movements of the
Pacific coast type.

(c) *Kainozoic Igneous Series.*

The Victorian basaltic rocks are certainly not associated with
fold movements, because throughout the Kainozoic Period in
Victoria there is no evidence of any earth movement of this type
except of a purely local character. On the other hand there is
abundant evidence of Kainozoic faulting. I understand that Mr.
D. J. Mahony is working out the evidence of this Kainozoic fault-
ing, so that I will not enter into the subject at any length. The
first record of Kainozoic faulting is due to Selwyn (13), who pointed
out the fault line along the eastern shore of Port Phillip. In
South Gippsland there is abundant evidence of post-Jurassic fault-

ing, and many of these movements are undoubtedly of Kainozoic age. The Newer Basalts of Victoria are mainly confined to the faulted area of South-Western Victoria. The Great Valley of Victoria is of the nature of a rift-valley, this area having been faulted down since the deposition of the Jurassic rocks. Bass Strait also represents another Kainozoic rift-valley.

The earth movements in Victoria during the Kainozoic period were of the Atlantic coast type, and on Harker's hypothesis we should therefore expect to find rocks of the alkaline branch. It has been shown that such do occur at Macedon (19), Coleraine (23) and Omeo (18), but with them we must associate the calcic basalts.

V. Petrographic Regions.

We are now in a position to criticise Harker's generalisation on the relationship of the alkali and calcic branches of igneous rocks to tectonic movements in the light of the evidence to be derived from a study of the Victorian igneous rocks.

In the first place, notwithstanding Harker's assertion that the characteristics of the two branches are too well known to need recapitulation, there is distinct uncertainty as to which branch a large number of rocks belong. In discussing the basalts of Skye (6) Harker himself finds difficulty in their classification. He considers that normally basalts belong to the calcic group, but that in this case they show alkaline affinities in the presence of various zeolites, including original analcime.

The Heathcotian diabases are probably associated with fault movement, but there is no evidence that they show the slightest sign of alkaline affinities. Zeolites are plentiful in the basalts of Collingwood, Flinders, and elsewhere in Victoria, and anorthoclase is sometimes found to be present, but the few analyses that have been published of the Victorian Kainozoic basalts agree very closely with the composition of basalts from other parts of the world, and there is absolutely no reason for placing them in the alkali branch. Yet these rocks must be associated with fault movements.

In our paper on the Macedon District (19) Professor Skeats and the author advanced evidence in support of the genetic associa- tion of the alkaline rocks of that area with the Kainozoic basalts of Victoria. At the same time it was pointed out that similar asso- ciations of alkaline rocks with basalts had been recorded by Daly (2) and Marshall (10). If this genetic relationship of alkaline

rocks with basalts be correct, then Harker's generalisation fails unless we assume that the basalts show alkaline affinities.

Turning to the granitic-dacite series of Victoria we see that they are associated with movements of the Pacific coast type, and consequently should be expected to belong to the Calcic Branch.

The analyses of the dacites from Macedon show an average of 2.55 per cent. of potash, 2.62 per cent. of soda, and 4.03 per cent. of lime, so that they must be classed as belonging to the Sub-alkali Group (Iddings), which is equivalent to Harker's Calcic or Pacific Branch.

In the same way the granodiorites may be shown to belong to the Sub-alkali Group.

The analyses of the granites from Dog Rocks, Cape Woolamai, Gabo Island and Mt. Buffalo show the following percentages :—

		Dog Rocks.	Cape Woolamai.	Gabo Island.	Mt. Buffalo.
K_2O	-	5.27	4.76	4.06	4.89
Na_2O	-	3.30	3.00	3.38	3.12
CaO	-	0.41	.65	1.31	0.84

An examination of a section of the granite from the Dog Rocks shows that it contains two felspars, one of which is orthoclase and the other a triclinic form showing exceedingly fine twin lamellae and undulose extinction, and which seems referable to anorthoclase. As this rock contains 8.57 per cent. of alkalies and only 0.41 per cent. of lime, it is quite impossible to stretch the definition of the Calcic Branch to include a rock of this composition. The granites of Cape Woolamai, Mt. Buffalo and Gabo Island must also be classed as belonging to the Alkaline Branch.

The variation diagram (Fig. 3) shows that if any reliance can be placed on variation diagrams, then the alkaline granites are genetically related to the subalkaline or calcic dacites and granodiorites, and that there is a gradual passage from alkaline to calcic types in the granitic-dacite series of Victoria.

It will be seen that the above evidence is in distinct opposition to Harker's generalisation. The calcic diabases of Heathcote and the calcic basalts of the Kainozoic Period are to be associated with movements of the Atlantic coast type and the alkaline granites of the Dog Rocks, Cape Woolamai and elsewhere, accompany movements of the Pacific coast type.

The conclusion then is that Harker's generalisation in its present form fails when applied to the elucidation of the association of igneous rocks and earth movements in Victoria.

VI. The Origin of the Victorian Rock Magmas.

In an earlier portion of this paper evidence has been given for regarding the Heathcotian diabases and the Kainozoic basalts as being associated with trough faulting, while the granites, grano-diorites, dacites, etc., were associated with intense earth folding. This means that the basalts, for we may regard the diabases as greatly altered basalts, were associated with one type of tectonic movement, while the granites, etc., were associated with a quite distinct type of movement.

If we turn to the generalised variation diagram (Fig. 4) of the differentiation products of the Victorian granitic magma, we find that the theoretical basic differentiation end product differs radi-cally in composition from normal basalt. This means that a basaltic rock could not be formed as a serial differentiation product from this magma.

In the case of the Macedon alkaline rocks it was shown that some of the rocks were apparently derived by the splitting up of a partial magma, and that the products so formed bore no serial relation-ship to one another.

In the Geelong and Heathcote districts we have a certain amount of evidence that some of the rocks were derived in a somewhat similar way by the splitting up of a magma.

Westward from Geelong and at the foot of the northern slope of the Barrabool Hills is a large outcrop of a basic rock which is best described as an epidiorite. Intruded through this rock is a well-defined dyke of granite porphyry. The field evidence is such that there is no doubt as to the relative ages of the two rocks.

Northward from this area lies the granite massif of the Dog Rocks. A comparison of sections of this granite with a section of the granite porphyry dyke from the southern area show that except for the difference in the coarseness of grain there is very little distinction between the two, and there is little doubt that they are genetically related. The granite area of the Dog Rocks is roughly triangular in outline, and at the south-eastern corner is an outcrop of epidorite. Microscopically this resembles very closely the epi-diorite from the southern area, and again they appear to be genetically related to one another. In this case, however, the epidiorite is apparently intrusive into the granite, and so is younger than that rock. Unfortunately the field evidence is not as conclusive as could be desired, so that the relationship of the two rocks cannot be stated to have been proved. The epidiorite occurs

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as an irregular mass on the lower slopes of the Dog Rocks. The
two rocks are in no place to be observed actually in contact, but
what I have taken for irregular veins of the epidiorite may be
traced out into the surrounding granite, but in all cases to no
great distance from the main mass. About half a mile to the west,
on the southern border of the area, is another small outcrop of
epidiorite, but again the relationship is obscured by surface soil.
In both cases, however, the epidiorite occurs at a lower level than
the general mass of the granite, and as before stated, from the
larger area veins of the epidiorite appear to run off from the main
mass into the neighbouring granite. Had it not been for the
evidence of the southern area I would not have hesitated in con-
cluding that the epidiorite was intrusive into the granite, and as
it is this conception accords best with the available evidence.
Through the kindness of Mr. E. J. Dunn, analyses of the granite
and epidiorite have been made for me by Mr. A. G. Hall at the
Mines Department Laboratory. The analysis of the granite has
already been quoted, but is given here for comparison with that of
the epidiorite, which is recorded for the first time.

TABLE XV.

		I.		II.
SiO_2	-	75.99	-	49.25
Al_2O_3	-	13.10	-	17.49
Fe_2O_3	-	0.57	-	1.25
Feo	-	0.61	-	3.95
Mgo	-	0.18	-	10.67
Cao	-	0.41	-	14.83
Na_2O	-	3.30	-	0.75
K_2o	-	5.27	-	0.06
H_2O	-	0.40	-	1.44
H_2O	-	0.14	-	0.14
CO_2	-	nil.	-	nil.
Tio_2	-	0.11	-	0.09
P_2O5	-	trace	-	trace
Mno	-	0.06	-	0.09
NiO	-	0.02	-	0.02
CoO	-	trace	-	trace
BaO	-	nil.	-	nil.
Li_2O	-	trace	-	trace
Cl.	-	trace	-	trace
SO_3	-	nil.	-	nil.
Total	-	100.16	-	100.03
Sp. Gravity		2.620	-	2.934

I.   Granite, Dog Rocks, Geelong.
II. Epidiorite, Dog Rocks, Geelong.

It will be seen that this analysis of epidiorite, even when re-calculated to 100 per cent., would not conform to the variation diagram of the Victorian Palaeozoic series.

The epidiorite, then, is clearly not related to the granite in a serial manner, and although the evidence is strongly in favour of the two rocks being derived from a common magma, they fail to show any chemical or mineralogical relationship to one another.

It is suggested that these two rocks were derived from a common magma by complementary differentiation, and that the basic differentiation product was intruded to the south, and the acid portion to the north. At the time of intrusion the differentiation was not quite complete, and in the southern area the residual acid portion separated out, and was intruded through the basic portion in the form of a dyke. The irregular character of the junction of the granite and epidiorite at the Dog Rocks suggests the possibility that in this case the completion of the differentiation took place *insitu*.

In the Heathcote area is a somewhat analogous occurrence. The rocks described from this area include diabase, porphyrite, diorite and an acid rock variously called aplite, granophyre, fine-grained granodiorite and micro-granite.

Professor Skeats (14) holds that the micro-granite is genetically related to the diabases and represents an acid residuum from the basic magma.

The diorite is not at all normal, and probably represents a hybrid rock due to a mixing of the diabasic and micro-granitic magmas.

One point of considerable importance is the absence in both cases of normal intermediate types. Harker (4), in discussing the North British Tertiary Province, mentions the occurrence of ultra-basic rocks, the eucrite group, and basic rocks associated with granites and granophyres, but points out that it is a broken series, types of mean acidity being absent.

Another interesting case of the association of acid and basic rocks without the presence of intermediate types is that of the laccolithic sheet of Sudbury, described by Coleman (1) and referred to by Harker (4).

While the latter considers that the separation out of the sulphides from the norites was probably due to the limited miscibility of the sulphide magma with the silicate magma, he doubts whether the separation of the norite from the overlying acid rocks may be attributed to the same cause.

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The evidence of the Geelong and Heathcote areas suggest that magmas of intermediate composition have split into two portions, an acid and a basic. We have also seen that a basaltic magma cannot be serially related to the Victorian granite-dacite series. This suggests the hypothesis which is tentatively advanced that wherever a molten magma of intermedite composition exists, whether it be a primary magma or a secondary magma derived by the fusion of pre-existing igneous and sedimentary rocks, then the primary differentiation is into an acid portion and a basic portion, possibly due to the limited miscibility of the two types.

Basaltic magmas appear to have a greater uniformity in composition, and to produce fewer subsidiary types, to which they are serially related, than the magmas which have produced granite, dacite, etc., so that possibly the governing factor in this primary differentiation is the separation out of a basic magma of fairly constant composition.

If this primary differentiation were incomplete, or if by assimilation of other material the balance between the various constituents in the basaltic magma was upset, then secondary differentiation might take place, causing a separation out of a subsidiary magma and leaving a normal basaltic magma.

If the subsidiary magma were molecularly unstable, then further differentiation of the serial or complementary type would be induced, giving rise to a varied facies such as is met with among the Macedon alkaline rocks.

In the case of the acid primary differentiation product, judging by the Victorian examples quoted the various types would be evolved by serial differentiation, with possibly some minor complementary differentiation as at Lilydale.

As in the case of the basic primary differentiation product, if the molecular balance be upset either by incomplete primary differentiation or by assimilation, then a subsidiary magma may separate out and give rise to rocks less normal in character. Basic segregations so common in the Victorian granites may be regarded as possibly representing such subsidiary differentiation caused by the magma assimilating foreign material during intrusion.

As the acid primary differentiation product would have a lower specific gravity than the basic portion, we might expect the acid portion to occupy the upper portion of the primary magma reservoir, and in case of crustal movements, due to lateral compression, might be more affected than the lower basic portion. On the other

hand, faulting would give rise to channels up which the more deeply-seated basic portion might find a passage to the surface. In cases where folding and faulting have accompanied one another we might be expected to get an association of the two types, and in such a case hybrid rocks caused by the mixing of portions of the two magmas might be expected to occur.

VII. Summary.

The aim of the present paper has been to discuss the relationship of certain Victorian igneous rocks and to see what deduction may be made from such study.

The differentiation of several series has been treated at some length, especially with reference to the use of variation diagrams, and it has been shown :—

1. Variation diagrams constructed from analyses which have been recalculated to 100 per cent. with the water omitted and with all the iron converted to ferrous oxide give a better representation of the serial relationship of a group of rocks than diagrams constructed from original analyses.

2. There is an apparent relationship between the shape of the variation curve of the total molecular ratios and the shape of the curves, indicating the serial relationship of the rocks. Thus in the Victorian Upper Palaeozoic series the variation of the total molecular ratios of the recalculated analyses (i.e., the molecular concentration) can be expressed by straight lines, and the variation of the oxides may also be expressed by straight lines. On the other hand the variation of the oxides in the Macedon Kainozoic series must be expressed by means of curved lines in agreement with the curvilinear variation of the molecular concentration.

3. The conception of the complementary differentiation of certain of the Macedon alkali rocks is upheld by the molecular concentration curve. A similar type of differentiation probably accounts for the origin of certain of the Upper Palaeozoic series occurring at Lilydale.

The limits of the differentiation of the Victorian Upper Palaeozoic series are discussed at some length, and it is found that the theoretical acid limit value is a bimineralic compound consisting approximately of 39 per cent. quartz and 61 per cent. alkali felspar, and that the theoretical basic limit value, if we neglect

the iron ores, is also a bimineralic compound containing approxi-
mately 41 per cent. of amphibole or pyroxene and 59 per cent. of
anorthite.

Harker's generalisation as to the relationship of branches of
igneous rocks to tectonic movements is criticised, and evidence is
advanced to show that in its present form it fails when applied to
Victoria.

The origin of igneous rocks is briefly dealt with, and it is sug-
gested that the primary differentiation of a parent magma is into
two portions, a basic and an acidic. The basic portion gives rise
to the basalts, gabbros, norites, etc., and the acid or dacitic magma
by serial differentiation produces andesites, rhyolites, granites, etc.
Other rocks are subordinate in amount and are believed to be due
to subsidiary differentiation of a partial magma from the basaltic
or dacitic magma when the molecular balance of the latter has
been upset by assimilation of foreign material or by incomplete
primary differentiation.

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